

Inhibitors of TGF-R signaling for treatment of CNS disorders

Specification

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The present invention relates to the use of oligonucleotides for the preparation of a pharmaceutical composition for the prevention or treatment of a disease, wherein neurogenesis and/or neuroregeneration has a beneficial effect, in particular a neurodegenerative disease like Morbus Alzheimer, Morbus Parkinson incl.

10 Multisystem-Atrophy, Progressive Supranuclear Palsy, Corticobasal Degeneration, Lewy Body Dementia, Amyotrophic Lateral Sclerosis and other Motor Neuron Disorders, Huntington's disease, Spinocerebellar Atrophies, Creutzfeldt Jakob and other severe Prion Diseases, Frontotemporal Dementia incl. Morbus Pick, AIDS Dementia Complex, Hallervorden Spatz Disease, Huntington's disease, a

15 cerebrovascular disease like Vascular Dementia, Stroke, Traumatic Brain and spinal cord Injury, Retinitis Pigmentosa, Macular Degeneration, Glaucoma, Depression and Schizophrenia, and developmental disorders like Down's syndrome.

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A number of severe neurodegenerative disorders have severe socioeconomic impact upon modern societies, e.g., disorders like Morbus Alzheimer, Developmental disorders with dementia (like Down's syndrome), Morbus Parkinson, Lewy Body Dementia, Frontotemporal Dementia, Morbus Pick, Amyotrophic Lateral Sclerosis, Spinocerebellar Atrophies; Creutzfeldt Jakob Disease, AIDS Dementia Complex, Vascular Dementia, Progressive Supranuclear Palsy, Corticobasal Degeneration,

25 Multisystem-Atrophy, Huntington's disease, Stroke, Traumatic Brain Injury, Retinitis Pigmentosa, Macular Degeneration, Glaucoma, Depression, Schizophrenia, and Multiple Sclerosis. The common pathophysiological cause is found in genetic, epigenetic or acquired defects - frequently resulting in aggregate formation or accumulation of cell debris- ultimately leading to progressive dysfunction and finally

30 to neuronal or glial cell death and structural disintegration. Microglia cells and perivascular resting macrophages are attracted and activated, trying to clear the cell and tissue debris. This may happen in a very short span of time, as in Creutzfeldt Jacob Disease, or over decades, as e.g. in Parkinson's Disease or Multiple Sclerosis. The activated microglial /macrophage cell population releases a number of

35 inflammatory cytokines into the extracellular matrix, draining these either into small venules or the CSF-space. Unfortunately, neurogenesis and neuroregeneration that could have an advantageous effect on the clinical course of these diseases described above (despite their individual specific pathophysiological mechanisms) is suppressed by so far unknown mechanisms. Thus, the technical problem underlying

the present invention is to provide means suitable for treating or preventing neurodegenerative disorders or at least symptoms associated with said disorders by interfering with the suppression of neurogenesis and neuroregeneration.

- 5 The solution of the said technical problem is achieved by providing the embodiments characterized in the claims. The TGF-beta family of proteins, namely TGF-beta1, TGF-beta2 and TGF-beta3 with their specific cell surface receptors TGF RI, TGF RII, TGF RIII are known to act on several crucial aspects of embryonal and mainly mesenchymal / neuroektodermal organ development. They allow embryonal stem
10 cells to differentiate into neuronal precursor cells, and are neuroprotective for injured mature neurons. It is further known that they have a critical impact upon hematopoietic stem cell differentiation, controlling proliferation and also differentiation. During the experiments leading to the present invention it was found that TGF-R, i.e. TGF RI and TGF RII are crucial factors involved in suppression of neurogenesis and
15 neuroregeneration and, accordingly, a compound which is capable of interfering with this biological activity of TGF R or TGF RII is useful for the treatment/prevention of neurodegenerative disorders and/or neuroinflammatory disorders.

To summarize, as a result of the experiments leading to the present invention:

- 20 1. A physiological regulatory circuit has been recognized that accounts for the level of effective CNS-reneration by precursor-/stem cells, although of course the individual components have been known (TGF- β , TGF-RII, cerebrospinal fluid compartment, vitreous, endolymphatic fluid, neuronal precursor cells, etc). This circuit - with the crucial target molecule TGF-RII expressed at the ventricular wall - is
25 responsible for the defunct neuroregeneration in the majority of CNS-pathology.
2. Interestingly the regulation takes places not via blood, lymphatics, or extracellular matrix but via fluid compartments (cerebrospinal fluid etc.), which have direct contact to neuronal cells and their precursors or stem cells.
- 30 3. A physiologically inhibitory circuit for neuronal/oligodendroglial or astrocytic renewal has been discovered as being an ideal target for strategies to repair damage within the CNS, overwhelmingly being applicable for almost all destructive pathology in the nervous system. From previous knowledge on TGF- β it has been tried rather to increase than decrease (see 5) TGF- β function in order to augment its known neuroprotective or immunosuppressive activities in the CNS: here we postulate to
35 decrease its inhibitory function on stem cell renewal by blocking TGF-RII signalling at the ventricular wall.
4. Although for a long time it has been speculated that inflammatory processes play a significant role in neurodegeneration, and a relative large amount of preclinical and clinical data seem to support this idea, the master circuit is now being disclosed,

that orchestrates all the single regulatory sub-circles, e.g. cytokines (IL-1, IL-6, IL-12) and others.

5. In addition, it might be noted that **Nature** has installed neuroprotection and an immunoprivileged CNS above neuroregeneration in priority: it has not been shown so far that the immunoprivileged and highly protected CNS (protected specifically against immune attacks and neuronal apoptosis), which is in significant part due to the TGF- β system, has deficits in neuroregeneration due to exactly this privilege and due to the same molecule TGF- β . The evolutionary concept seems to argue in favour for acute neuroprotection of a highly sophisticated CNS and its most complex functioning; in this context, individual neuroregeneration seems less important for evolution than neuroprotection of the individual.

The Regulatory Circuit

- 15 Physiologically neurogenesis of the brain allows continuous repair/replacement of malfunctioning or ageing neuronal, oligodendroglial or astrocytic cells by respective precursor cells. Neurogenesis for repair in the brain is regulated by the TGF- β -TGF-R (especially TGF RII, but also TGF RI) system, via the cerebrospinal fluid; the main orchestrators are microglial/macrophage lineage cells producing TGF- β and secreting it via extracellular space into the CSF (as well as within vitreous, endolymphatics) compartment, and neuronal precursor cells/stem cells, that receive this signal via CSF (as well as into vitreous, endolymphatics) through highly expressed TGF-RII or TGF-RI on their surface structures, or an ependymal lining with identical receptors. In the majority of CNS-pathology neurogenesis is severely impaired or malfunctioning. The regulation of neurogenesis is adjusted, usually suppressed (!) by the activation of microglial cells / macrophages from within the CNS, taking place in the context of any specific disease pathology. Activated microglial cells / macrophages by this route - CSF to subventricular zone/other neurogenic zones - suppress the regeneration of the neurodegenerating, acute and chronic inflammatory, hypoxic, atherosclerotic or ageing brain parenchyma. Not only neuronal differentiation is affected, but also oligodendroglial and astrocytic cell lineages. All molecules that interfere with this circuit to improve neuronal / oligodendroglial / astrocytic regeneration are claimed as treatment. Methods for diagnostics, prophylaxis, prevention or prognosis of CNS pathology employing this circuit are also of high importance, conceivably for monitoring the effects of therapeutic intervention.

Brief description of the drawings

Fig. 1: TGF-beta1 inhibits proliferation of adult rodent neural stem and precursor cells

A) Adult rodent neural stem and precursor cell (NSC) cultures were treated with various concentrations (0, 5, 10, 50 ng/ml) of recombinant human TGF-beta1 for 7 days. On day 7 viable cells were counted by Trypan Blue exclusion assay in a hemocytometer. The data are expressed as average cell numbers \pm SD from three experiments performed in triplicate. B) shows the effect of TGF-beta1 on human fetal neural precursor cells.

Fig. 2: The effect of TGF-beta1 on NSCs is reversible

Adult rodent neural stem and precursor cell cultures were treated with 10 ng/ml of recombinant human TGF-beta1 for 7 days. On day 7 cells were dissociated, counted by Trypan Blue exclusion assay and TGF-beta1 pre-treated cells were reseeded in with or without 10 ng/ml TGF-beta1. This procedure was performed every 7 days. The data are expressed as average cell numbers \pm SD from three experiments performed in triplicate.

Fig. 3: Antibodies against TGF-betaRII can reduce TGF-beta1 effects on adult rodent NSCs

Adult rodent NSC cultures were treated with 10 ng/ml of recombinant human TGF-beta1 for 7 days in the presence or absence of anti-TGF-betaRII antibody (10 μ g/ml). On day 7 viable cells were counted by Trypan Blue exclusion assay in a hemocytometer. The data are expressed as average cell numbers \pm SD from three experiments performed in triplicate.

Fig. 4: Soluble TGF-RII inhibits TGF- β 1-induced suppression of NSC proliferation

Adult rodent NSC cultures were treated with 10 ng/ml of recombinant human TGF-beta1 for 7 days in the presence or absence of soluble anti-TGF-betaRII (500 ng/ml). On day 7 viable cells were counted by Trypan Blue exclusion assay in a hemocytometer. The data are expressed as average \pm SD from three experiments performed in triplicate.

Figure 5:

TGF- β RII-expressing cells can be isolated using cell sorting techniques.

Adult rodent NSCs were prepared as described in example 1. Cells expressing TGF-bRII were purified using antibodies against TGF-bRII. About 20% of NSCs express the receptor and this cell population can be enriched by this approach.

Fig. 6: Antisense oligonucleotides against TGF- β RII inhibit the TGF- β 1 induced down-regulation of adult neural stem and precursor proliferation in vitro.

It was shown that the TGF- β 1 induced inhibition of neural stem and precursor proliferation was completely and specifically blocked by the antisense treatment.

Fig. 7: In vivo treatment with TGF-RII specific antisense oligonucleotides rescues the TGF- β 1 induced blockade of cell proliferation in the adult brain.

Figure 7 demonstrates the TGF- β 1 induced down-regulation of cell proliferation in the hippocampal dentate gyrus (figure 7A) and in the subventricular zone (figure 7B). Treatment with missense oligonucleotide did not block this effect, whereas antisense oligonucleotide treatment blocked the TGF- β 1 effect (figure 7 A and B).

Fig. 8: In vivo treatment with TGF-RII specific antisense oligonucleotides prevent from TGF- β 1 induced blockade of cell proliferation in the adult brain

Figure 8 demonstrates that the TGF- β 1 induced down-regulation of cell proliferation in the hippocampal dentate gyrus (figure 8A) and in the subventricular zone (figure 8B) can be prevented by pre-treatment with TGF- β RII antisense oligonucleotide treatment.

In the disorders described above, microglial cells, and potentially perivascular resting macrophages, are attracted from protein aggregates, cell debris, inflammation, inflammatory response in atherosclerosis, or acute trauma/hypoxia associated cell death. This may be an acute, subacute or chronic process. During the activation process the activated microglial cell population (including macrophages from the vessel wall or other sources) releases a number of inflammatory cytokines into the extracellular matrix, draining either into small venules or directly into the CSF-space. These cytokines will reach the CSF-compartment and will be immediately available at all locations, which are surrounded to some extent by CSF. Among these cytokines is TGF-beta. It was demonstrated (Monje, M. L., H. Toda, et al. (2003). "Inflammatory blockade restores adult hippocampal neurogenesis." Science 302 (5651) : 1760-1765) that neuroinflammation inhibits neurogenesis and that inflammatory blockade with indomethacin, a common nonsteroidal anti-inflammatory drug, restores neurogenesis after endotoxininduced inflammation and augments neurogenesis after cranial irradiation.

However, the prior art does not disclose TGF-beta as the main regulator down-regulating neurogenesis and neurorepair after injury or under pathological conditions. In contrast, the prior art considered TGF-beta as a neuroprotective agent preventing

injured or lesioned neurons from cell death, and tried to up-regulate TGF-beta in CNS disease conditions.

5 Zhang et al. (Zhang, J. M., R. Hoffmann, et al. (1997). "Mitogenic and antiproliferative signals for neural crest cells and the neurogenic action of TGF-beta1." Dev. Dyn. 208(3): 375-386.) demonstrate that TGF-beta has an effect on developing quail neural crest cells. Here, TGF-beta inhibited proliferation of both pluripotent neural crest cells (and/or their immediate derivatives) and of committed melanogenic cells, causing a decrease in colony size. In addition, and in contrast to the present
10 invention, neurogenesis increased significantly in the presence of TGF-beta. The number per colony of both adrenergic cells and sensory neuron precursors increased in TGF-beta-treated neuroblast-positive colonies.

TGF-betas have important roles in cell growth and differentiation, organ
15 development, matrix formation, wound repair and immune function. While TGF-beta is a potent growth-inhibitory substance for many cell types, it stimulates proliferation of fibroblasts and osteoblasts. It is also a potent stimulator of extracellular matrix production by fibroblasts and osteoblasts, inhibits matrix degradation and up-regulates receptors for matrix interaction. TGF-beta1 has been implicated as a key
20 causative factor in the pathogenesis of liver fibrosis and at least as one crucial mediator of both the beneficial and detrimental effects of cyclosporine A on the immune system and the kidney. In addition, various chronic progressive fibrotic kidney disorders in humans and experimental models have been shown to be associated with stimulation of the TGF-beta system.

25 TGF-beta1 down-regulates G1 and G2 cyclin-dependent kinases and cyclins in terms of both kinase activity and protein amount. TGF-beta1 also inhibits phosphorylation of the product of the retinoblastoma tumor suppressor gene pRb at multiple serine and threonine residues in human myeloid leukemia cells. The under-phosphorylated
30 pRb associates with transcription factor E2F-4 in G1 phase, whereas the phosphorylated pRb mainly binds to E2F-1 and E2F-3. Because TGF-beta1 up-regulates p130(pRb family member) /E2F-4 complex formation and down-regulates p107 (pRb family member) /E2F-4 complex formation, with E2F-4 levels remaining constant, these results suggest that E2F-4 is switched from p107 to pRb and p130
35 when cells exit from the cell cycle and arrest in G1 by the action of TGF-beta1. The "cdk inhibitor" p27 is both a positive and a negative regulator of TGF-beta1-mediated cell cycle control. Although TGF-beta1 has been reported to be a selected inhibitor of normal primitive hematopoietic stem cells, TGF-beta inhibits both primitive and more differentiated myeloid leukemia cell lines. Most attention was drawn on TGF-

beta1's neuroprotective activity , its role in neural development and on its role in modulating immune responses. TGF-beta1 has been shown in a number of studies to be neuroprotective in vitro and in vivo. Agonist studies have demonstrated that TGF-beta1 reduces neuronal cell death and infarct size following middle cerebral artery occlusion (MCAO), while conversely, antagonist studies have shown increased neuronal cell death and infarct size after MCAO, suggesting that TGF-beta1 has a neuroprotective role in cerebral ischemia. Recent work with adenoviral-mediated overexpression of TGF-beta1 in vivo in mice has further implicated a neuroprotective role for TGF-beta1 in cerebral ischemia, as evidenced by a reduction in neuronal cell death, infarct size, and neurological outcome. Additionally, numerous in vitro studies have documented the neuroprotective ability of TGF-beta1 in neurons from a variety of species, including rats, mice, chicks, and humans. Of significant interest, TGFbeta1 was shown to be protective against a wide variety of death-inducing agents/insults, including hypoxia/ischemia, glutamate excitotoxicity, beta-amyloid, oxidative damage, and human immunodeficiency virus. The neuroprotective effect of TGF-beta1 has been related to its ability to maintain the mitochondrial membrane potential, to stabilize Ca^{2+} homeostasis, to increase the expression of the anti-apoptotic proteins Bcl-2 and Bcl-xl, to inhibit caspase-3 activation and to induce plasminogen activator inhibitor-1. Studies in embryonic stem cells have demonstrated a primitive neural stem cell as a component of neural lineage specification that is negatively regulated by TGF-beta-related signalling. Endogenous expression of TGF-alpha, another TGF family member, has been shown to positively regulate adult neurogenesis. TGF-alpha is necessary for the full proliferation of progenitor cells present in the subependyma and the full production of the neuronal precursors that migrate to the olfactory bulb. In TGF-alpha knock out mice, proliferation of these progenitor cells also is diminished with age, likely because of a lengthening of the cell cycle. Senescence or the absence of endogenous TGF-alpha does not affect the numbers of neural stem cells isolated in vitro in the presence of epidermal growth factor.

The use of TGF-beta for immunomodulation in humans is severely limited by its toxicity, including excessive stimulation of matrix production, nephrotoxicity and other detrimental effects. TGF-beta has oncogenic potential and has been implicated in glomerulopathies, pulmonary fibrosis, scleroderma and chronic graft versus host disease. In addition, while TGFbeta is an extremely potent immunosuppressive cytokine, several lines of evidence indicate that chronic stimulation of TGF-beta expression - both disease-related or in transgenic animal models - can paradoxically lead to or enhance autoimmune inflammation.

There is increasing evidence that the powerful anti-inflammatory properties of TGF-beta as a negative regulator of T-cell immune response play a key role in the pathophysiology of a variety of CNS pathologies. Therefore, this cytokine is regarded as an injury-related peptide and a potential target for therapeutic intervention. Neuroinflammation and microglial pathology are associated with many neurological diseases. Here, the most classical ones are clearly neuro-immunological diseases such as Multiple Sclerosis. But it includes also diseases of cognition in which memory loss features prominently, such as Alzheimer's Disease, Lewy Body Dementia, AIDS Dementia Complex, Vascular Dementia, or less prominently, such as Pick's Disease, Progressive Supranuclear Palsy, Corticobasal Degeneration, and Creutzfeldt-Jakob Disease. In addition, inflammatory programs are activated after acute lesions such as stroke, traumatic brain and spinal cord injuries. In different animal models for Creutzfeldt-Jacob Disease activation of microglia and up-regulation of TGF-beta1 has been reported (Baker, C. A., Z. Y. Lu, et al. (1999). "Microglial activation varies in different models of Creutzfeldt-Jakob disease." J Virol 73(6): 5089-5097).

Among the hundreds of different neurodegenerative disorders, the attention has been given only to a handful, including Alzheimer disease, Parkinson disease, Huntington's disease, and amyotrophic lateral sclerosis. It is worth to mention that the same neurodegenerative process can affect different areas of the brain, making a given disease appear very different from a symptomatic standpoint. Neurodegenerative disorders of the central nervous system (CNS) can be grouped into diseases of the cerebral cortex (Alzheimer disease), the basal ganglia (Parkinson disease), the brain-stem and cerebellum, or the spinal cord (Amyotrophic Lateral Sclerosis).

Examples for neurodegeneration and neurodegenerative disorders are: Alzheimer's diseases, Parkinson's disease, Creutzfeldt Jakobs disease (CJD), new variant of Creutzfeldt Jakobs disease (nvCJD), Hallervorden Spatz disease, Huntington's disease, multisystem atrophy, dementia, frontotemporal dementia, motor neuron disorders, amyotrophic lateral sclerosis, spinal muscular atrophy, spinocerebellar atrophies (SCAs), schizophrenia, affective disorders, major depression, meningoencephalitis, bacterial meningoencephalitis, viral meningoencephalitis, CNS autoimmune disorders, Multiple Sclerosis (MS), acute ischemic / hypoxic lesions, CNS trauma, head trauma, arteriosclerosis, atherosclerosis, microangiopathic dementia, Binswanger' disease Leukoaraiosis, retinal degeneration, cochlear degeneration, macular degeneration, cochlear deafness, AIDS-related dementia, retinitis pigmentosa, fragile X-associated tremor/ataxia syndrome (FXTAS),

progressive supranuclear palsy (PSP), striatonigral degeneration (SND), olivopontocerebellar degeneration (OPCD), Shy Drager syndrome (SDS).

Influencing the levels of TGF-beta1

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Up-Regulation of TGF-beta1 and its effects

Many studies tried to increase TGF-beta1 levels for neuroprotective or immunoregulatory purposes. Agonist studies have demonstrated that TGF-beta1 reduces neuronal cell death and infarct size following middle cerebral artery occlusion (MCAO), while conversely, antagonist studies have shown increased neuronal cell death and infarct size after MCAO, suggesting that TGF-beta1 has a neuroprotective role in cerebral ischemia. Recent work with adenoviral-mediated overexpression of TGF-beta1 in vivo in mice has further implicated a neuroprotective role for TGF-beta1 in cerebral ischemia, as evidenced by a reduction in neuronal cell death, infarct size, and neurological outcome. Additionally, numerous in vitro studies have documented the neuroprotective ability of TGF-beta1 in neurons from a variety of species, including rats, mice, chicks, and humans. Of significant interest, TGFbeta1 was shown to be protective against a wide variety of death-inducing agents/insults, including hypoxialischemia, glutamate excitotoxicity, beta-amyloid, oxidative damage, and human immunodeficiency virus. The neuroprotective effect of TGF-beta1 has been related to its ability to maintain the mitochondrial membrane potential, to stabilize Ca^{2+} homeostasis, to increase the expression of the anti-apoptotic proteins Bcl-2 and Bcl-xl, to inhibit caspase-3 activation and to induce plasminogen activator inhibitor-1.

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The use of TGF-beta for immunomodulation in humans is severely limited by its toxicity, including excessive stimulation of matrix production, nephrotoxicity and other detrimental effects. TGF-beta has oncogenic potential and has been implicated in glomerulopathies, pulmonary fibrosis, scleroderma and chronic graft versus host disease. In addition, while TGF beta is an extremely potent immunosuppressive cytokine, several lines of evidence indicate that chronic stimulation of TGF-beta expression – both disease-related or in transgenic animal models – can paradoxically lead to or enhance autoimmune inflammation.

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Our main finding is that the identical TGF- β described in it's protective effects upon the CNS above, is the main negative regulatory molecule of CNS-stem cell repair in physiology and in almost all CNS pathology: TGF- β - produced by microglial cells (either at low physiological levels or at higher levels in response to disease) leaks through the intercellular matrix into the CSF. There it may freely and directly interact

with highly regulated and expressed TGF-RII and TGF-RI on the precursor / stem cell population of the CNS at the subependymal progenitor-containing cell layer zone or potentially other areas of CNS-stem cell renewal. The finding consists of a negative regulation, resulting in low stem cell renewal in case of high CSF-TGF- β levels and vice versa. Unusual and most remarkably, the extreme high expression level and activity of TGF-RII is located at the site of precursor / stem cell proliferation, in our experiments the SVZ or the hippocampus. Unusual is also the transmission of the signal through a buffering solution, as for example cerebrospinal fluid (CSF). It is therefore a complete regulatory circle, where physiological and pathological regulation are very similar, but vary only by intensity (in other words: the level of TGF- β in the CSF, and level of TGF-R expression at the target cells). The individual disease pathology phenotype is characterized by such diverse changes, as genetic deficits (e.g. Synucleinopathies, Superoxide Dismutase Mutations, Trinucleotide Repeat Disorders) or trauma, hypoxia, vascular disease or inflammation, or CNS-ageing. The executor of the disease pathology, however, is always the microglial cell/macrophage population - produced TGF- β : On one hand it is neuroprotective and immunosuppressive, helping to deescalate the acute inflammatory damage to the parenchyma and the neuronal loss potentially inflicted by the disease pathology. Indirectly - as a *Janus Head* - the same molecule prevents the CNS from damage repair by the own stem cells/precursor cells through interfering with the TGF- β - TGF-R loop at the precursor or stem cell level, thereby significantly suppressing stem cell proliferation. In this case, as stem cells not only those cells derived from precursor cells from within the CNS should be looked at, but conceivably also those stem cells/precursor cells that try to invade the CNS parenchyma from the vessels respectively the bone marrow. This also means that by simply decreasing TGF- β levels in the parenchyma, the neuroprotective / immunosuppressive effects upon the CNS would be annihilated leading to severe acute damage by inflammation and / or direct neuronal apoptosis.

A local intervention at the TGF-R-level therefore seems the only attractive pathway for stable intervention in favour of repair, not endangering the beneficial effects of TGF- β for the brain. Thus, the present invention relates to antisense oligonucleotides interfering with the biological activity of TGF-beta1 upon the precursor / stem cell pool expressing TGF-R. Said oligonucleotides or pharmaceutical compositions including at least one of said oligonucleotides are useful for the diagnosis / prophylaxis / prevention or treatment of a disease, wherein neurogenesis or neuroregeneration has a beneficial effect. They are also useful in the therapeutic prevention (for example after stroke or head injury) - as shown in our experiments - before the mechanisms described hereafter will be effective.

The term "interfering" as used herein means modulating, preferably reducing or eliminating, the biological activity of TGF-R and/or TGF-R_{II} or its expression. The modulation of the biological activity can be effected by direct interaction or binding of a compound to TGF-R, preferably, TGF-R_{II} or by indirect interaction, e.g., by interacting with a compound that is associated with the biological activity of TGF-R and/or TGF-R_{II}. Suitable compounds acting as agents targeting TGF-betaR_I, -R_{II}, -R_{III}, or its signal transduction to interfere with this regulatory circuit with the aim to improve neuroregeneration or increase neuronal/hematopoietic stem cell or precursor cell recruitment to the CNS, including all types of local or systemic transplantation (e.g. ex vivo propagation, allogeneic cells) are listed below:

- (a) Plasmids, vectors or natural/synthetic/mutated viruses, oligonucleotides of various types of modification (e.g. PTO, LNA, 2'F-ANA, protein-nucleotide complexes, RNAi, siRNA or mikro miRNA, Methylmethoxy-, Phosphoramidates, PNA, Morpholino, Phosphoramidate, Cyclohexen (CeNA), gap-meres, ribozymes, aptamers, CpG-oligos, DNA-zymes, riboswitches, or lipids or lipid containing molecules,
- (b) peptides, peptide complexes, including all types of linkers,
- (c) small molecules, modifiers of rafts or caveoli,
- (d) modifiers of golgi apparatus,
- (e) antibodies and their derivatives, especially chimeras, Fab-fragments, Fc-fragments, or
- (f) carriers, liposomes, nanoparticles, complexes, or any other delivery systems containing the above named constructs, can be used to target the above mentioned circuit to restore or improve neuroregeneration.

However, most preferred among the above-mentioned agents are antisense oligonucleotides, since they interfere with the formation of TGF-R or TGF-R_{II} at a very early stage. The main advantages of these molecules rest in their extremely high target specificity, combined with their extremely good systemic and local tolerance; they are very well suited for local application into the CNS, either into the parenchyma or the CSF - space. In addition, they are very stable, and may thus be easily applied from an implanted pumping system. Their cost-efficacy is also remarkable.

Thus, in preferred embodiments of the present invention, the compound useful for interfering with the expression of the gene encoding TGF-R or TGF-R_{II}, is an antisense oligonucleotide.

The generation of suitable antisense oligonucleotides includes determination of a site or sites within the TGF-R gene or TGF-R_{II} gene for the antisense interaction to occur such that the desired effect, e.g., inhibition of expression of the protein, will result. A preferred intragenic site is (a) the region encompassing the translation initiation or termination codon of the open reading frame (ORF) of the gene or (b) a region of the mRNA which is a "loop" or "bulge", i.e., not part of a secondary structure. Once one or more target sites have been identified, oligonucleotides are chosen which are sufficiently complementary to the target, i.e., hybridize sufficiently well and with sufficient specificity, to give the desired effect.

Thus, the present invention relates to antisense oligonucleotides having a sub-sequence of SEQ ID NO 1 or SEQ ID NO 2 or SEQ ID NO 94 or SEQ ID NO 95 or SEQ ID NO 96 comprising 8 to 50 nucleobases and mimetics thereof. Said oligonucleotides represent a part of the SEQ ID NO 1 or 2 or SEQ ID NO 94 to 96 with 8 to 50 nucleotide bases. Furthermore, the antisense oligonucleotides comprising 8 to 50 nucleobases do not have to be an exact sub-sequence of SEQ ID NO 1 or 2 or SEQ ID NO 94 to 96. It is sufficient if the antisense oligonucleotides are at least 80%, preferably 84%, more preferably 88% and most preferably 92% identical to a sub-sequence found in of SEQ ID NO 1 or 2 or SEQ ID NO 94 or 95 or 96. Preferred oligonucleotides have a sequence at least 80% identical to a sub-sequence of SEQ ID NO 1 or 2 or 94 or 95 or 96 comprising 8 to 50 nucleobases, wherein said sequence is capable of hybridizing sufficiently with the region encompassing the translation initiation or termination codon of the open reading frame of the gene encoding TGF-R or TGF-R_{II}, or a region of the mRNA encoding TGF-R or TGF-R_{II} which is a "loop" or "bulge" and which is not part of a secondary structure. That means, these antisense oligonucleotides have a sequence at least 80% complementary with the corresponding region of the gene encoding TGF-R or TGF-R_{II}, or preferably have a sequence at least 80% complementary with (a) the region encompassing the translation initiation or termination codon of the open reading frame of the gene encoding TGF-R or TGF-R_{II}, or (b) a region of the mRNA encoding TGF-R or TGF-R_{II} which is a "loop" or "bulge", i.e., not part of a secondary structure.

Preferred are antisense oligonucleotides of 8 to 50, preferably 15 to 25 nucleobases, able to hybridize sufficiently with the region encompassing the translation initiation or termination codon of the open reading frame of the gene encoding TGF-R or TGF-R_{II}, or a region of the mRNA encoding TGF-R or TGF-R_{II} which is a "loop" or "bulge" and which is not part of a secondary structure.

Preferred are the following elongated sequences of SEQ ID NO 3 which can be represented by the following general formula:



5

wherein X is selected from the group comprising the following oligonucleotides:

ACAGGACGATGTGCAGCGGCCACAGGCCCTGAG,

CAGGACGATGTGCAGCGGCCACAGGCCCTGAG,

AGGACGATGTGCAGCGGCCACAGGCCCTGAG,

10 GGACGATGTGCAGCGGCCACAGGCCCTGAG,

GACGATGTGCAGCGGCCACAGGCCCTGAG,

ACGATGTGCAGCGGCCACAGGCCCTGAG,

CGATGTGCAGCGGCCACAGGCCCTGAG,

GATGTGCAGCGGCCACAGGCCCTGAG,

15 ATGTGCAGCGGCCACAGGCCCTGAG, TGTGCAGCGGCCACAGGCCCTGAG,

GTGCAGCGGCCACAGGCCCTGAG, TGCAGCGGCCACAGGCCCTGAG,

GCAGCGGCCACAGGCCCTGAG, CAGCGGCCACAGGCCCTGAG,

AGCGGCCACAGGCCCTGAG, GCGGCCACAGGCCCTGAG,

CGGCCACAGGCCCTGAG, GGCCACAGGCCCTGAG,

20 GCCACAGGCCCTGAG, CCACAGGCCCTGAG, CACAGGCCCTGAG,

ACAGGCCCTGAG, CAGGCCCTGAG, AGGCCCTGAG, GGCCCTGAG,

GGCCCTGAG, CCCCTGAG, CCCTGAG, CCTGAG, CTGAG, TGAG, GAG, AG, G,

and wherein Z is selected from the group comprising the following oligonucleotides:

GCAGACCCCGCTGCTCGTCATAGACCGAGCCCC,

25 GCAGACCCCGCTGCTCGTCATAGACCGAGCCCC,

GCAGACCCCGCTGCTCGTCATAGACCGAGCCC,

GCAGACCCCGCTGCTCGTCATAGACCGAGCC,

GCAGACCCCGCTGCTCGTCATAGACCGAGC,

GCAGACCCCGCTGCTCGTCATAGACCGAG,

30 GCAGACCCCGCTGCTCGTCATAGACCGA,

GCAGACCCCGCTGCTCGTCATAGACCG,

GCAGACCCCGCTGCTCGTCATAGACC, GCAGACCCCGCTGCTCGTCATAGAC,

GCAGACCCCGCTGCTCGTCATAGA, GCAGACCCCGCTGCTCGTCATAG,

GCAGACCCCGCTGCTCGTCATA, GCAGACCCCGCTGCTCGTCAT,

35 GCAGACCCCGCTGCTCGTCA, GCAGACCCCGCTGCTCGTC,

GCAGACCCCGCTGCTCGT, GCAGACCCCGCTGCTCG,

GCAGACCCCGCTGCTC, GCAGACCCCGCTGCT, GCAGACCCCGCTGC,

GCAGACCCCGCTG, GCAGACCCCGCT, GCAGACCCCGC, GCAGACCCCG,

GCAGACCCC, GCAGACCC, GCAGACC, GCAGAC, GCAGA, GCAG, GCA, GC, G,

and wherein X and Z together comprise not more than 34 nucleobases and mimetics thereof.

More preferred are the following oligonucleotide sequences and variants or mimetics thereof:

5	SEQ ID NO 3:	5'-CAGCCCCCGACCCATG-3'
	SEQ ID NO 4:	5'-GCTGATGCCTGTCACTTGAA-3'
	SEQ ID NO 5:	5'-GCCATGGAGTAGACATCGGT-3'
	SEQ ID NO 6:	5'-GCAACAGCTATTGGGATGGT-3'
10	SEQ ID NO 7:	5'-GTGCAGGGGAAAGATGAAAA-3'
	SEQ ID NO 8:	5'-GTATCAGCATGCCCTACGGT-3'
	SEQ ID NO 9:	5'-GGATCCAGATTTTCCTGCAA-3'
	SEQ ID NO 10:	5'-GGAGAAGCAGCATCTTCCAG-3'
	SEQ ID NO 11:	5'-GAGCTCTTGAGGTCCCTGTG-3'
15	SEQ ID NO 12:	5'-GAGACCTTCCACCATCCAAA-3'
	SEQ ID NO 13:	5'-TAGCTGGCTGTGAGACATGG-3'
	SEQ ID NO 14:	5'-TTTTGAAACGCTGTGCTGAC-3'
	SEQ ID NO 15:	5'-TCAGCCAGTATTGTTTCCCC-3'
	SEQ ID NO 16:	5'-TCACACAGGCAGCAGGTTAG-3'
20	SEQ ID NO 17:	5'-TCAGGAATCTTCTCCTCCGA-3'
	SEQ ID NO 18:	5'-TGGTAGTGTTTAGGGAGCCG-3'
	SEQ ID NO 19:	5'-TATCCCCACAGCTTACAGGG-3'
	SEQ ID NO 20:	5'-AGCCTCTTTCCTCATGCAAA-3'
	SEQ ID NO 21:	5'-ATGTCATTTCCCAGAGCACC-3'
25	SEQ ID NO 22:	5'-AGGAATCTTCTCCTCCGAGC-3'
	SEQ ID NO 23:	5'-AGCCATGGAGTAGACATCGG-3'
	SEQ ID NO 24:	5'-ATGCTACTGCAGCCACACTG-3'
	SEQ ID NO 25:	5'-CCTTCTCTGCTTGTTTCTGG-3'
	SEQ ID NO 26:	5'-CCAGGAGAAATAAGGGCACA-3'
30	SEQ ID NO 27:	5'-CAGCAGCTCTGTGTTGTGGT-3'
	SEQ ID NO 28:	5'-CCCCTGTTAGCCAGGTCAT-3'
	SEQ ID NO 29:	5'-CAGCCCCCGACCCATGGCAGACCC-3'
	SEQ ID NO 30:	5'-CAGCCCCCGACCCATGGCAGACC-3'
35	SEQ ID NO 31:	5'-CAGCCCCCGACCCATGGCAGAC-3'
	SEQ ID NO 32:	5'-CAGCCCCCGACCCATGGCAGA-3'
	SEQ ID NO 33:	5'-CAGCCCCCGACCCATGGCAG-3'
	SEQ ID NO 34:	5'-CAGCCCCCGACCCATGGCA-3'
	SEQ ID NO 35:	5'-CAGCCCCCGACCCATGGC-3'
40	SEQ ID NO 36:	5'-CAGCCCCCGACCCATGG-3'

	SEQ ID NO 37:	5'-GCAGCCCCCGACCCATGGCAGACC-3'
	SEQ ID NO 38:	5'-GCAGCCCCCGACCCATGGCAGAC-3'
	SEQ ID NO 39:	5'-GCAGCCCCCGACCCATGGCAGA-3'
	SEQ ID NO 40:	5'-GCAGCCCCCGACCCATGGCAG-3'
5	SEQ ID NO 41:	5'-GCAGCCCCCGACCCATGGCA-3'
	SEQ ID NO 42:	5'-GCAGCCCCCGACCCATGGC-3'
	SEQ ID NO 43:	5'-GCAGCCCCCGACCCATGG-3'
	SEQ ID NO 44:	5'-GCAGCCCCCGACCCATG-3'
10	SEQ ID NO 45:	5'-AGCAGCCCCCGACCCATGGCAGAC-3'
	SEQ ID NO 46:	5'-AGCAGCCCCCGACCCATGGCAGA-3'
	SEQ ID NO 47:	5'-AGCAGCCCCCGACCCATGGCAG-3'
	SEQ ID NO 48:	5'-AGCAGCCCCCGACCCATGGCA-3'
	SEQ ID NO 49:	5'-AGCAGCCCCCGACCCATGGC-3'
15	SEQ ID NO 50:	5'-AGCAGCCCCCGACCCATGG-3'
	SEQ ID NO 51:	5'-AGCAGCCCCCGACCCATG-3'
	SEQ ID NO 52:	5'-GAGCAGCCCCCGACCCATGGCAGA-3'
	SEQ ID NO 53:	5'-GAGCAGCCCCCGACCCATGGCAG-3'
20	SEQ ID NO 54:	5'-GAGCAGCCCCCGACCCATGGCA-3'
	SEQ ID NO 55:	5'-GAGCAGCCCCCGACCCATGGC-3'
	SEQ ID NO 56:	5'-GAGCAGCCCCCGACCCATGG-3'
	SEQ ID NO 57:	5'-GAGCAGCCCCCGACCCATG-3'
25	SEQ ID NO 58:	5'-TGAGCAGCCCCCGACCCATGGCAG-3'
	SEQ ID NO 59:	5'-TGAGCAGCCCCCGACCCATGGCA-3'
	SEQ ID NO 60:	5'-TGAGCAGCCCCCGACCCATGGC-3'
	SEQ ID NO 61:	5'-TGAGCAGCCCCCGACCCATGG-3'
30	SEQ ID NO 62:	5'-TGAGCAGCCCCCGACCCATG-3'
	SEQ ID NO 63:	5'-CTGAGCAGCCCCCGACCCATGGCA-3'
	SEQ ID NO 64:	5'-CTGAGCAGCCCCCGACCCATGGC-3'
	SEQ ID NO 65:	5'-CTGAGCAGCCCCCGACCCATGG-3'
35	SEQ ID NO 66:	5'-CTGAGCAGCCCCCGACCCATG-3'
	SEQ ID NO 67:	5'-CCTGAGCAGCCCCCGACCCATGGC-3'
	SEQ ID NO 68:	5'-CCTGAGCAGCCCCCGACCCATGG-3'
	SEQ ID NO 69:	5'-CCTGAGCAGCCCCCGACCCATG-3'
40	SEQ ID NO 70:	5'-CCCTGAGCAGCCCCCGACCCATGG-3'
	SEQ ID NO 71:	5'-CCCTGAGCAGCCCCCGACCCATG-3'
	SEQ ID NO 72:	5'-CCCCTGAGCAGCCCCCGACCCATG-3'

Still more preferred are the following oligonucleotide sequences as well as variants and mimetics thereof:

	SEQ ID NO 33:	5'-CAGCCCCCGACCCATGGCAG-3'
	SEQ ID NO 34:	5'-CAGCCCCCGACCCATGGCA-3'
5	SEQ ID NO 35:	5'-CAGCCCCCGACCCATGGC-3'
	SEQ ID NO 36:	5'-CAGCCCCCGACCCATGG-3'
	SEQ ID NO 41:	5'-GCAGCCCCCGACCCATGGCA-3'
	SEQ ID NO 42:	5'-GCAGCCCCCGACCCATGGC-3'
	SEQ ID NO 43:	5'-GCAGCCCCCGACCCATGG-3'
10	SEQ ID NO 44:	5'-GCAGCCCCCGACCCATG-3'
	SEQ ID NO 49:	5'-AGCAGCCCCCGACCCATGGC-3'
	SEQ ID NO 50:	5'-AGCAGCCCCCGACCCATGG-3'
	SEQ ID NO 51:	5'-AGCAGCCCCCGACCCATG-3'
	SEQ ID NO 56:	5'-GAGCAGCCCCCGACCCATGG-3'
15	SEQ ID NO 57:	5'-GAGCAGCCCCCGACCCATG-3'
	SEQ ID NO 62:	5'-TGAGCAGCCCCCGACCCATG-3'
	SEQ ID NO 73:	5'-ATGTGAAGATGGGCAAGACC-3'
	SEQ ID NO 74:	5'-ATCTCCATGTGAAGATGGGC-3'
20	SEQ ID NO 75:	5'-AACGGCCTATCTCGAGGAAT-3'
	SEQ ID NO 76:	5'-AACATCGTCGAGCAATTTCC-3'
	SEQ ID NO 77:	5'-AATCCAACCTCCTTTGCCCTT-3'
	SEQ ID NO 78:	5'-AAACCTGAGCCAGAACCTGA-3'
	SEQ ID NO 79:	5'-AGGGCGATCTAATGAAGGGT-3'
25	SEQ ID NO 80:	5'-AGTGCACAGAAAGGACCCAC-3'
	SEQ ID NO 81:	5'-ACACTGGTCCAGCAATGACA-3'
	SEQ ID NO 82:	5'-TTCCTGTTGACTGAGTTGCG-3'
	SEQ ID NO 83:	5'-CACTCTGTGGTTTGGAGCAA-3'
	SEQ ID NO 84:	5'-CAAGGCCAGGTGATGACTTT-3'
30	SEQ ID NO 85:	5'-CACACTGGTCCAGCAATGAC-3'
	SEQ ID NO 86:	5'-CTGACACCAACCAGAGCTGA-3'
	SEQ ID NO 87:	5'-CTCTGCCATCTGTTTGGGAT-3'
	SEQ ID NO 88:	5'-TCAAAAAGGGATCCATGCTC-3'
	SEQ ID NO 89:	5'-TGACACCAACCAGAGCTGAG-3'
35	SEQ ID NO 90:	5'-TGATGCCTTCCTGTTGACTG-3'
	SEQ ID NO 91:	5'-TTCCTGTTGACTGAGTTGCG-3'
	SEQ ID NO 92:	5'-TTCTCCAAATCGACCTTTGC-3'
	SEQ ID NO 93:	5'-GGAGAGTTCAGGCAAAGCTG-3'

Excluded from the scope of the present substance claims are the following two known sequences: 5'-GATCTTGACTGCCACTGTCTC-3' (J. Clin. Endocrinology & Metabolism 2003, 88(10), 4967-4976) and 5'-CATGGCAGCCCCCGTC-3' (Developmental Biology 1996, 180, 242 – 257).

5

Especially preferred is the sequence SEQ ID NO 3: 5'-CAGCCCCCGACCCATG-3'.

Consequently, the present invention is also directed to sequences which are closely related to any one of SEQ ID NO 3 to SEQ ID NO 93. Said sequences are referred to as "variants" herein. The antisense oligonucleotides can be modified by several different ways. Modifications within the backbone are possible and refer to oligonucleotides wherein the phosphorus atoms in their internucleoside backbone are partially or completely replaced by other atoms. Preferred modified oligonucleotide backbones include, for instance, phosphorothioates, chiral phosphorothioates, phosphorodithioates, phosphotriester, aminoalkylphosphotriesters, methyl, ethyl and C₃–C₁₀–alkyl phosphonates including 3'-alkylene phosphonates and chiral phosphonates, phosphinates, phosphoramidates including 3'-amino phosphoramidate and aminoalkylphosphoramidates, thionophosphoramidates, thionoalkylphosphonates, thionoalkylphosphotriesters and boranophosphates having normal 3'-5' linkages, 2'-5' linked analogs of these, and those having inverted polarity wherein the adjacent pairs of nucleoside units are linked 3'-5' to 5'-3' or 2'-5' to 5'-2'. Various salts, mixed salts and free acids forms thereof are also included.

Preferred are also variants of SEQ ID NO 3 to SEQ ID NO 93 wherein at the 3' terminal end and/or at the 5' terminal end 1, 2, 3, 4, or 5 further nucleobases are added. Such further nucleobases are preferably the five nucleobases within the SEQ ID NOs 1, 2, 94, 95, or 96 which come directly prior or after the respective sequence. Furthermore, said preferred variants may have 1, 2, 3, or 4 nucleobase exchanges, i.e. within said preferred variants, one, two, three or four nucleotides may be substituted by another nucleobase. It should be stressed that these variants may also contain any of the modifications of the backbone or the base or sugar moiety disclosed herein, such as phosphorothioate backbones.

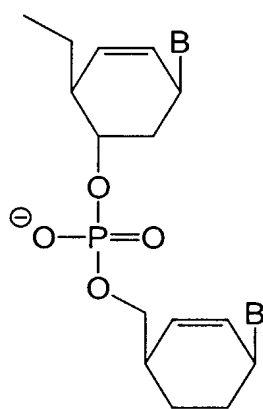
Preferred modified oligonucleotide backbones that do not include a phosphorus atom therein have backbones that are formed by short chain alkyl or cycloalkyl internucleoside linkages, mixed heteroatom and alkyl or cycloalkyl internucleoside linkages. These include those having morpholino linkages (formed in part from the sugar portion of a nucleoside); siloxane backbones, sulfide, sulfoxide and sulfone backbones; formacetyl and thioformacetyl backbones; methylene formacetyl and

thioformacetyl backbones, alkene containing backbones, sulfamate backbones; methyleneimino and methylenehydrazino backbones; sulfonate and sulfonamide backbones; amide backbones, mixtures of the afore-mentioned types of backbones and other backbones having mixed N, O, S, P, and CH₂ component parts.

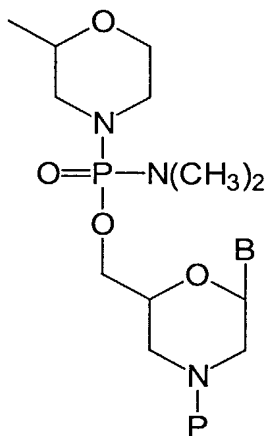
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Further preferred embodiments of the present invention comprise oligonucleotides with phosphorothioate backbones or heteroatom backbones, and in particular with -CH₂-NH-O-CH₂-, -CH₂-N(CH₃)-O-CH₂- (known as a methylene (methylimino) or MMI backbone), -CH₂-O-N(CH₃)-CH₂-, -CH₂-N(CH₃)-N(CH₃)-CH₂- and
 10 -O-N(CH₃)-CH₂-CH₂- (wherein the native phosphodiester backbone is represented as -O-P-O-CH₂-). Also oligonucleotides having morpholino moieties in their backbone or having a morpholino backbone structure or having a aminoalkylamide backbone are preferred (cf. below). Oligonucleotides may also have sugar mimetics such as cyclobutyl moieties in place of the pentofuranosyl sugar.

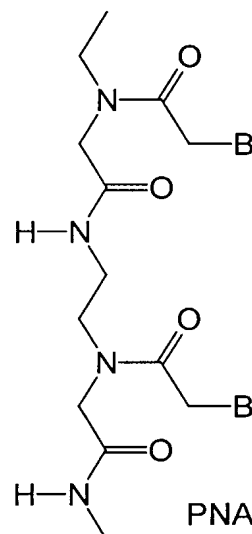
15



cyclohexane mimetics



morpholino mimetics



B refers to the base moiety such as the purin or pyrimidin group which may be further derivatized.

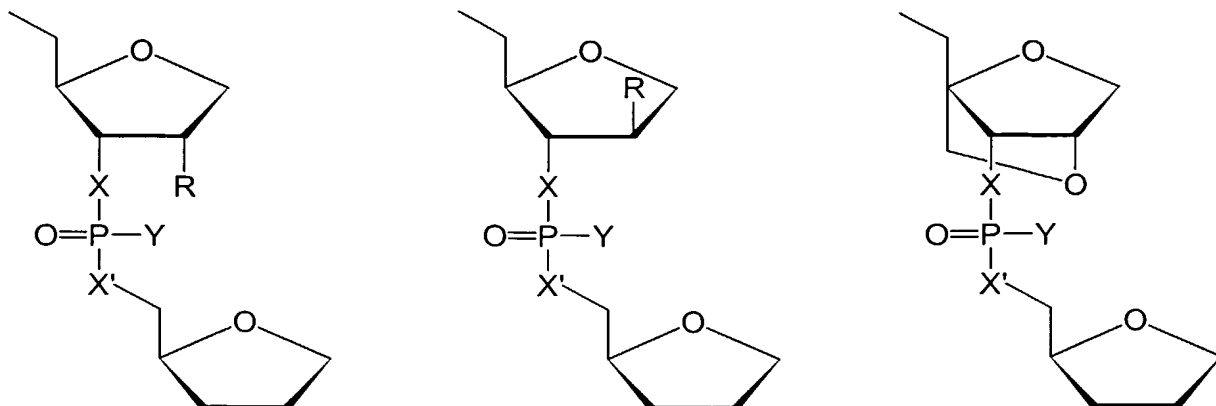
20

Another modification of the oligonucleotides of the present invention involves chemically linking to the oligonucleotide one or more moieties or conjugates which enhance the activity, cellular distribution or cellular uptake of the oligonucleotide. Modified oligonucleotides may also contain one or more substituted or modified sugar moieties. Preferred oligonucleotides comprise one of the following at the 2'
 25 position: -OH, -F, -O-alkyl, -S-alkyl, -N-alkyl, -O-alkenyl, -S-alkenyl, -N-alkenyl, -O-alkynyl, -S-alkynyl, -N-alkynyl, -O-alkyl-O-alkyl, wherein the alkyl, alkenyl and alkynyl may be substituted or unsubstituted C₁ to C₁₀ alkyl or C₂ to C₁₀ alkenyl and C₂ to C₁₀ alkynyl. A particularly preferred modified sugar moiety is a

2'-O-methoxyethyl sugar moiety (2'-OCH₂CH₂OCH₃, also known as 2'-O-(2-methoxyethoxy) or 2'-MOE) and 2'-dimethylaminoethoxy such as O(CH₂)₂ON(CH₃) (known as 2'-DMAOE). Also particularly preferred are O[(CH₂)_nO]_mCH₃, O(CH₂)_nOCH₃, O(CH₂)_nNH₂, O(CH₂)_nCH₃, O(CH₂)_nONH₂,
 5 O(CH₂)_nON[(CH₂)_nCH₃], where n and m are independently of each other integer from 1 to 10. Other preferred modifications include 2'-methoxy, 2'-aminopropoxy and 2'-fluoro. Other preferred oligonucleotides comprise one of the following groups at the 2' position: -OCH₃, -OC₂H₅, -OC₃H₇, -O-cyclo-C₃H₅, -OCH(CH₃)₂,
 10 -OC(CH₃)₃, -OC₄H₉, -OPh, -OCH₂-Ph, -NO₂, -F, -Cl, -Br, -I, -N₃, -CN, -OCN, -NCO, -SCN, -NCS, -COCH₃, -COC₂H₅, -COC₃H₇, -CO-cyclo-C₃H₅, -COCH(CH₃)₂, -CF₃, -SH, -SCH₃, -SC₂H₅, -SC₃H₇, -S-cyclo-C₃H₅, -SOCH₃, -SOC₂H₅, -SOC₃H₇, -SO-cyclo-C₃H₅, -SO₂CH₃, -SO₂C₂H₅, -SO₂C₃H₇, -SO₂-cyclo-C₃H₅, -NH₂, -NHCH₃, -NHC₂H₅, -NHC₃H₇, -NH-cyclo-C₃H₅, -N(CH₃)₂, -N(C₂H₅)₂, -N(C₃H₇)₂, -N(cyclo-C₃H₅)₂, -N[CH(CH₃)₂]₂-CH₃, -C₂H₅,
 15 -C₃H₇, -CH(CH₃)₂, -C₄H₉, -CH₂-CH(CH₃)₂, -CH(CH₃)-C₂H₅, -C(CH₃)₃, -C₅H₁₁, -CH(CH₃)-C₃H₇, -CH₂-CH(CH₃)-C₂H₅, -CH(CH₃)-CH(CH₃)₂, -C(CH₃)₂-C₂H₅, -CH₂-C(CH₃)₃, -CH(C₂H₅)₂, -C₂H₄-CH(CH₃)₂, -C₆H₁₃, -C₃H₆-CH(CH₃)₂, -C₂H₄-CH(CH₃)-C₂H₅, -CH(CH₃)-C₄H₉, -CH₂-CH(CH₃)-C₃H₇, -C₂H₄-C(CH₃)₃, -CH(CH₃)-CH₂-CH(CH₃)₂, -CH(CH₃)-CH(CH₃)-C₂H₅, -CH₂-CH(CH₃)-CH(CH₃)₂,
 20 -CH₂-C(CH₃)₂-C₂H₅, -C(CH₃)₂-C₃H₇, -C(CH₃)₂-CH(CH₃)₂, -CH(CH₃)-C(CH₃)₃, C₇-C₁₀ alkyl, substituted C₁-C₁₀ alkyl, alkylaryl, arylalkyl, O-C₁-C₁₀ alkyl, O-arylalkyl, heterocycloalkyl, heterocycloalkylaryl, aminoalkylamino, polyalkylamino, substituted silyl, an RNA leaving group, a reporter group, an intercalator, a group for improving the pharmacokinetic and/or pharmacodynamic properties of the
 25 oligonucleotide, or substituents having similar properties. Also preferred are the deoxy nucleobases.

Similar modifications may also be made at other positions on the nucleotide, particularly the 3' position of the sugar on the 3' terminal nucleotide or in 2'-5' linked
 30 oligonucleotides and the 5' position of 5' terminal nucleotide.

Preferred modifications can be represented by the following structure fragment:



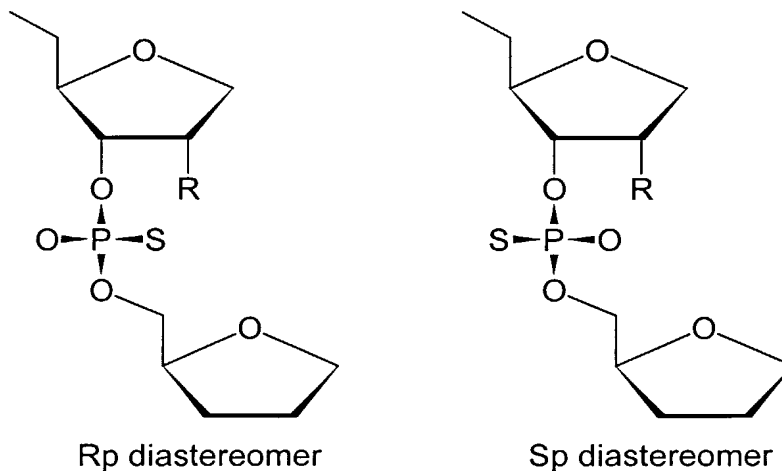
wherein

R represents any of the above-mentioned substituents for position 2' and especially -H, -F, -OH, -NH₂, -OCH₃, -OCH₂CH₂OCH₃,

- 5 X and X' are independently of each other -O-, -NH-, -S-, -CH₂-, and
Y represents -O⁻, -S⁻, -N(CH₃)₂, -OCH₃, -SCH₃.

More preferred are variants wherein X and X' represent oxygen and Y represents sulfur.

Furthermore, pure diastereomeric oligonucleotides or mimetics or variants thereof are
10 preferred. Especially preferred are Sp- and Rp-diastereomers:



- Most preferred are also the sequences SEQ ID NO 3 to SEQ ID NO 93, and
15 especially SEQ ID NO 3, wherein one or more of the modifications disclosed herein
are present. Preferred are phosphorothioate moieties in the backbone or complete
phosphorothioate backbones and within said phosphorothioates the Rp and Sp
diastereomers are preferred.

- 20 The oligonucleotides of the present invention may also include nucleobase
substitutions. Nucleobases are the four standard nucleotide bases adenine (A),

thymine (T), guanine (G), and cytosine (C). Modified nucleobases include other synthetic and natural nucleobases such as 5-methylcytosine (5-me-C), 5-hydroxymethyl cytosine, xanthine, hypoxanthine, 2-aminoadenine, 6-methyl and other alkyl derivatives of adenine and guanine, 2-propyl and other alkyl derivatives of adenine and guanine; uracile (U), 6-carboxyuracile, N⁶-methyl-adenine, 5-halouracil, 5-halocytosine, 5-propynyl uracil, 5-propynyl cytosine, 6-azo uracil, 6-azo cytosine, 6-azo thymine, 5-uracil (pseudouracil), 4-thiouracil; 8-halo-, 8-amino-, 8-thiol-, 8-thioalkyl-, 8-hydroxyl- and other 8-substituted adenines and guanines; 5-halo- particularly 5-bromo-, 5-trifluoromethyl- and other 5-substituted uracils and cytosines; 7-methylguanine; 7-methyladenine, 8-azaguanine, 8-azaadenine, 7-deazaguanine, 7-deazaadenine, 3-deazaguanine and 3-deazaadenine, 2-thiouracil, 2-thiothymine and 2-thiocytosine etc., with 5-methylcytosine substitutions being preferred since these modifications have been shown to increase nucleic acid duplex stability.

Preferred are variants having the sequence of any one of SEQ ID NO 3 to SEQ ID NO 93, wherein one, two, three or four nucleobases are substituted by other nucleobases or chemically modified nucleobases. A variant shall refer to a sequence of SEQ ID NO 3 to SEQ ID NO 93, wherein one to four nucleobases are, for instance, substituted by uracile (U), 5-halouracil, 5-methyl-cytosine, and/or N⁶-methyl-adenine. Especially preferred are variants of SEQ ID NO 3, wherein one, two or three nucleobases are substituted by the above-mentioned moieties.

"Oligonucleotide" refers to an oligomer or polymer of ribonucleic acid (RNA) or deoxyribonucleic acid (DNA) or mimetics or variants thereof. This term includes oligonucleotides composed of naturally-occurring nucleobases, sugars and covalent internucleoside (backbone) linkages as well as oligonucleotides having non-naturally-occurring portions which function similarly. Such modified or substituted oligonucleotides are often preferred over native forms, because of desirable properties such as, for example, enhanced cellular uptake, enhanced affinity for nucleic acid target and increased stability in the presence of nucleases. While antisense oligonucleotides are a preferred form of the antisense compound, the present invention comprehends other oligomeric antisense compounds, including but not limited to oligonucleotide mimetics such as are described below. The antisense compounds in accordance with this invention comprise from about 8 to about 50 nucleobases (i.e. from about 8 to about 50 linked nucleosides), preferably 9 – 42, 10 – 36, 11 – 32, 12 – 30, 13 – 28, 14 – 26, and most preferably 15 – 25 nucleobases.

Particularly preferred antisense compounds are antisense oligonucleotides, even more preferably those comprising from about 15 to about 25 nucleobases.

Antisense compounds include ribozymes, external guide sequences (EGS), oligonucleotides (oligozymes), and other short catalytic RNAs or catalytic oligonucleotides which hybridize to the target nucleic acid and inhibit its expression.

- 5 The term "salts" refers to physiologically and/or pharmaceutically acceptable salts of the compounds, especially the antisense oligonucleotides of the present invention. Pharmaceutically acceptable base addition salts are formed with inorganic bases or bases. Examples for suitable organic and inorganic bases are bases derived from metal ions, e.g., aluminum, alkali metal ions, such as sodium or potassium, alkaline
10 earth metal ions such as calcium or magnesium, or an amine salt ion or alkali- or alkaline-earth hydroxides, -carbonates or -bicarbonates. Examples include aqueous LiOH, NaOH, KOH, NH₄OH, potassium carbonate, ammonia and sodium bicarbonate, ammonium salts, primary, secondary and tertiary amines, such as, e.g., tetraalkylammonium hydroxide, lower alkylamines such as methylamine, t-
15 butylamine, procaine, ethanolamine, arylalkylamines such as dibenzylamine and N,N-dibenzylethylenediamine, lower alkylpiperidines such as N-ethylpiperidine, cycloalkylamines such as cyclohexylamine or dicyclohexylamine, morpholine, glucamine, N-methyl- and N,N-dimethylglucamine, 1-adamantylamine, benzathine, or salts derived from amino acids like arginine, lysine, ornithine or amides of originally
20 neutral or acidic amino acids, chlorprocaine, choline, procaine or the like.

The compounds of the invention which are basic, may form pharmaceutically acceptable salts with organic and inorganic acids. Examples of suitable acids for such acid addition salt formation are hydrochloric acid, hydrobromic acid, sulfuric
25 acid, phosphoric acid, acetic acid, citric acid, oxalic acid, malonic acid, salicylic acid, p-aminosalicylic acid, malic acid, fumaric acid, succinic acid, ascorbic acid, maleic acid, sulfonic acid, phosphonic acid, perchloric acid, nitric acid, formic acid, propionic acid, gluconic acid, lactic acid, tartaric acid, hydroxymaleic acid, pyruvic acid, phenylacetic acid, benzoic acid, p-aminobenzoic acid, p-hydroxybenzoic acid,
30 methanesulfonic acid, ethanesulfonic acid, nitrous acid, hydroxyethanesulfonic acid, ethylenesulfonic acid, p-toluenesulfonic acid, naphthylsulfonic acid, sulfanilic acid, camphersulfonic acid, china acid, mandelic acid, o-methylmandelic acid, hydrogenbenzenesulfonic acid, picric acid, adipic acid, D-o-tolyltartaric acid, tartronic acid, α -toluic acid, (o, m, p)-toluic acid, naphthylamine sulfonic acid, and other mineral or
35 carboxylic acids well known to those skilled in the art. The salts are prepared by contacting the free base form with a sufficient amount of the desired acid to produce a salt in the conventional manner.

The free base forms may be regenerated by treating the salt with a suitable dilute aqueous base solution such as dilute aqueous sodium hydroxide, potassium carbonate, ammonia and sodium bicarbonate. The free base forms differ from their corresponding salt forms somewhat in certain physical properties, such as solubility in polar solvents, but the salts are otherwise equivalent to their corresponding free base forms for purposes of this invention.

Alternatively, the pharmaceutical composition of the invention contains a vector allowing to transcribe an antisense oligonucleotide of the invention, e.g., in a mammalian host. Preferably, such a vector is a vector useful for gene therapy. Preferred vectors useful for gene therapy are viral vectors, e.g. adenovirus, baculovirus, herpes virus, vaccinia, or, more preferably, an RNA virus such as a retrovirus. Even more preferably, the retroviral vector is a derivative of a murine or avian retrovirus. Examples of such retroviral vectors which can be used in the present invention are: Moloney murine leukemia virus (MoMuLV), Harvey murine sarcoma virus (HaMuSV), murine mammary tumor virus (MuMTV) and Rous sarcoma virus (RSV). Most preferably, a non-human primate retroviral vector is employed, such as the gibbon ape leukemia virus (GaLV), providing a broader host range compared to murine vectors. Since recombinant retroviruses are defective, assistance is required in order to produce infectious particles. Such assistance can be provided, e.g., by using helper cell lines that contain plasmids encoding all of the structural genes of the retrovirus under the control of regulatory sequences within the LTR. Suitable helper cell lines are well known to those skilled in the art. Said vectors can additionally contain a gene encoding a selectable marker so that the transduced cells can be identified. Moreover, the retroviral vectors can be modified in such a way that they become target specific. This can be achieved, e.g., by inserting a polynucleotide encoding a sugar, a glycolipid, or a protein, preferably an antibody. Those skilled in the art know additional methods for generating target specific vectors. Further suitable vectors and methods for in vitro- or in vivo-gene therapy are described in the literature and are known to the persons skilled in the art; see, e.g., WO 94/29469 or WO 97/00957. In order to achieve expression only in the target organ, e.g., brain tissue, the DNA sequences for transcription of the antisense oligonucleotides can be linked to a tissue specific promoter and used for gene therapy.

Within an oligonucleotide structure, the phosphate groups are commonly referred to as forming the internucleoside backbone of the oligonucleotide. The normal linkage or backbone of RNA and DNA is a 3' to 5' phosphodiester linkage. Specific examples of preferred antisense compounds or variants useful in the present

invention include oligonucleotides containing modified backbones or non-natural internucleoside linkages. Oligonucleotides having modified backbones include those that retain a phosphorus atom in the backbone and those that do not have a phosphorus atom in the backbone. Modified oligonucleotide backbones which can result in increased stability are known to the person skilled in the art, preferably such modification is a phosphorothioate linkage or the replacement of one or more phosphate groups (phosphoric acid group) by a phosphonate (phosphonic acid) group or by sulfate (sulfuric acid) group or by a sulfonate (sulfonic acid) group or by a sulfoxide. A preferred oligonucleotide mimetic is an oligonucleotide mimetic that has been shown to have excellent hybridization properties, and is referred to as a peptide nucleic acid (PNA). In PNA compounds, the sugar-backbone of an oligonucleotide is replaced with an amide containing backbone, in particular an aminoethylglycine backbone. The nucleobases are retained and are bound directly or indirectly to aza nitrogen atoms of the amide portion of the backbone (see, e.g., Nielsen et al., Science 254 (1991), 1497-1500.)

In the context of this invention, "hybridization" means hydrogen bonding, which may be Watson-Crick, Hoogsteen or reversed Hoogsteen hydrogen bonding, between complementary nucleoside or nucleotide bases. As used herein, the term "complementary" refers to the capacity for precise pairing between two nucleotides. For example, if a nucleotide at a certain position of an oligonucleotide is capable of hydrogen bonding with a nucleotide at the same position of a DNA or RNA molecule, then the oligonucleotide and the DNA or RNA are considered to be complementary to each other at that position. The oligonucleotide and the DNA or RNA are complementary to each other when a sufficient number of corresponding positions in each molecule are occupied by nucleotides which can hydrogen bond with each other. Thus, "specifically hybridizable" and "complementary" are terms which are used to indicate a sufficient degree of complementarity or precise pairing such that stable and specific binding occurs between the oligonucleotide and the DNA or RNA target. It is understood in the art that the sequence of an antisense compound does not need to be 100% complementary to that of its target nucleic acid to be specifically hybridizable. An antisense compound is specifically hybridizable when binding of the compound to the target DNA or RNA molecule interferes with the normal function of the target DNA or RNA to cause a loss of utility, and there is a sufficient degree of complementarity to avoid non-specific binding of the antisense compound to non-target sequences under conditions in which specific binding is desired, i.e., in the case of therapeutic treatment.

In other preferred oligonucleotide mimetics, both the sugar and the internucleoside linkage, i.e. the backbone of the nucleotide units are replaced with novel groups. The base units are maintained for hybridization with an appropriate nucleic acid target compound. An example for such an oligonucleotide mimetic that has been
5 shown to have excellent hybridization properties, is referred to as peptide nucleic acid (PNA). In PNA compounds, the sugar-backbone of an oligonucleotide is replaced with an amide containing backbone, in particular with an aminoethylglycine backbone. The nucleobases are retained and are bound directly or indirectly to aza nitrogen atoms of the amide portion of the backbone.

10 Another modification of the oligonucleotides of the invention involves chemically linking to the oligonucleotide one or more moieties or conjugates which enhance the activity, cellular distribution or cellular uptake of the oligonucleotide. Such moieties include lipid moieties such as a cholesterol moiety, cholic acid, a thioether, hexyl-S-
15 tritylthiol, a thiocholesterol, an aliphatic chain, e.g., dodecandiol or undecyl residues, a phospholipid such as dihexadecyl-rac-glycerol or triethylammonium-1,2-di-O-hexadecyl-rac-glycero-3H-phosphonate, a polyamine or a polyethylene glycol chain, or adamantane acetic acid, a palmityl moiety, or an octadecylamine or hexylamino-carbonyl-oxysterol moiety. The present invention also includes antisense
20 compounds which are chimeric compounds. "Chimeric" antisense compounds or "chimeras," in the context of this invention, are antisense compounds, particularly oligonucleotides, which contain two or more chemically distinct regions, each made up of at least one monomer unit, i.e., a nucleotide in the case of an oligonucleotide compound. These oligonucleotides typically contain at least one region wherein the
25 oligonucleotide is modified so as to confer upon the oligonucleotide increased resistance to nuclease degradation, increased cellular uptake, and/or increased binding affinity for the target nucleic acid. An additional region of the oligonucleotide may serve as a substrate for enzymes capable of cleaving RNA:DNA or RNA:RNA hybrids. By way of example, RNase H is a cellular endonuclease which cleaves the
30 RNA strand of an RNA:DNA duplex. Activation of RNase H, therefore, results in cleavage of the RNA target, thereby greatly enhancing the efficiency of oligonucleotide inhibition of gene expression. Consequently, comparable results can often be obtained with shorter oligonucleotides when chimeric oligonucleotides are used, compared to phosphorothioate deoxyoligonucleotides hybridizing to the same
35 target region. Chimeric antisense compounds of the invention may be formed as composite structures of two or more oligonucleotides, modified oligonucleotides, oligonucleosides and/or oligonucleotide mimetics as described above. Such compounds have also been referred to in the art as hybrids or gapmers.

Especially, the present invention relates to the use of the antisense oligonucleotides disclosed herein or variants or mimetics thereof for prophylaxis and treatment of neurodegenerative disorders, neurotrauma, neurovascular and neuroinflammatory incl postinfectious disorders. The term "neurodegenerative disorders and neuroinflammatory disorders" refers to Alzheimer's diseases, Parkinson's disease, Creutzfeldt Jakob disease (CJD), new variant of Creutzfeldt Jakobs disease (nvCJD), Hallervorden Spatz disease, Huntington's disease, multisystem atrophy, dementia, frontotemporal dementia, motor neuron disorders, amyotrophic lateral sclerosis, spinal muscular atrophy, spinocerebellar atrophies (SCAs), schizophrenia, affective disorders, major depression, meningoencephalitis, bacterial meningoencephalitis, viral meningoencephalitis, CNS autoimmune disorders, Multiple Sclerosis (MS), acute ischemic / hypoxic lesions incl stroke, CNS trauma, head trauma, arteriosclerosis, atherosclerosis, microangiopathic dementia, Binswanger' disease, leukoaraiosis, retinal degeneration, cochlear degeneration, macular degeneration, cochlear deafness, AIDS-related dementia, retinitis pigmentosa, fragile X-associated tremor/ataxia syndrome (FXTAS), progressive supranuclear palsy (PSP), striatonigral degeneration (SND), olivopontocerebellar degeneration (OPCD), Shy Drager syndrome (SDS).

More general, the present invention relates to the use of the antisense oligonucleotides disclosed herein or variants or mimetics thereof for treating diseases which are associated with up-regulated or enhanced signalling of TGF-R and/or TGF-R_{II}, e.g. through elevated levels of TGF-beta. The antisense oligonucleotides thereby inhibit the expression of TGF-R and/or TGF-R_{II}. Instead of the antisense oligonucleotides or in combination with the antisense oligonucleotides, antisense compounds may be used. Antisense compounds refer to vectors as disclosed herein allowing to transcribe an antisense oligonucleotide or to ribozymes, external guide sequences (EGS), oligozymes, and short catalytic RNAs or catalytic oligonucleotides which hybridize to the target nucleic acid encoding TGF-R or TGF-R_{II}. Said antisense compounds inhibit the expression of TGF-R or TGF-R_{II}. Thus, in said cases the amount of TGF-R and/or TGF-R_{II} present during disease state is decreased.

The antisense oligonucleotides and the antisense compounds disclosed herein are useful for regeneration and functional reconnection of damaged neural pathways and for treatment of various neurodegenerative disorders and neuroinflammatory disorders.

In a further preferred embodiment of the present invention, the compound useful for interfering with the biological activity of TGF-R and/or TGF-R_{II} is a compound reducing or inhibiting the binding of TGF- β 1 to its receptor. Preferred examples of such compounds are (neutralizing) antibodies directed against a TGF- β receptor; see
5 Lin et al., 1992, preferably the TGF- β receptor II. The term „antibody“, preferably, relates to antibodies which consist essentially of pooled monoclonal antibodies with different epitopic specificities, as well as distinct monoclonal antibody preparations. Monoclonal antibodies are made from an antigen containing, e.g., a fragment of TGF-R or TGF-R_{II} or a corresponding receptor by methods well known to those
10 skilled in the art. As used herein, the term "antibody" (Ab) or "monoclonal antibody" (Mab) is meant to include intact molecules as well as antibody fragments (such as, for example, Fab and F(ab')₂ fragments) which are capable of specifically binding to protein. Fab and F(ab')₂ fragments lack the Fc fragment of intact antibody, clear more rapidly from the circulation, and may have less non-specific tissue binding than
15 an intact antibody. (Wahl et al., J. Nucl. Med. 24: 316-325 (1983)). Thus, these fragments are preferred, as well as the products of a FAB or other immunoglobulin expression library. Moreover, antibodies useful for the purposes of the present invention include chimerical, single chain, and humanized antibodies.

20 Further preferred compounds for the use of the present invention are soluble TGF- β receptors. Such soluble TGF β receptors are fusion proteins between Fc regions of antibodies and the extracellular domain of TGF β receptors. Such molecules have a high affinity to soluble TGF-b1. Therefore, the concentration of free TGF-b1 is drastically reduced. According to the manufacturers protocol (R&D Systems,
25 Germany), a DNA sequence encoding the 159 amino acid residue extracellular domain of human TGF- β R_{II} (Lin et al., Cell 1992, 68(4), 775-785) was fused to the Fc region of human IgG1 and the chimeric protein was expressed in a mouse myeloma cell line NSO.

30 The term "soluble" as used herein in the context of receptors preferably relates to fragments of the receptor only comprising the extracellular domain(s) of the receptor or a part thereof which can still bind its natural ligand, e.g., TGF- β 1. The person skilled in the art can determine such fragments based on the known amino acid sequences of the receptors and the determination of the extracellular domain of the
35 receptors can be carried out by use of well known methods, e.g., by computer programs (hydrophilicity plot). In a particular preferred embodiment of the use of the present invention, said soluble TGF- β receptor is the TGF- β receptor II.

The present invention also relates to a method for identifying a compound interfering with (a) the biological activity of TGF-R and/or TGF-R_{II} or the expression of TGF-R and/or TGF-R_{II}, or (b) the TGF- β 1/TGF-R signaling, comprising the steps of:

- (a) incubating a candidate compound with a test system comprising TGF- β 1 and neuronal precursor cells; and
- (b) assaying the expression of active TGF receptors or the proliferation of the neuronal precursor cells; wherein
- (c) an abolition of (i) the suppression of expression of active TGF receptors or (ii) suppression of proliferation of the neuronal precursor cells compared to the test system in the absence of said test compound is indicative of the presence of a candidate compound having the desired properties.

Examples of such candidate molecules include antibodies, oligonucleotides, proteins (e.g., receptors), or small molecules. Such molecules can be rationally designed using known techniques. Preferably, said test system used for screening comprises substances of similar chemical and/or physical properties, most preferably said substances are identical. The compounds which can be prepared and identified according to a use of the present invention may be expression libraries, e.g., cDNA expression libraries, peptides, proteins, nucleic acids, antibodies, small organic compounds, ligands, hormones, peptidomimetics, PNAs or the like. More recently, WO 98/25146 described further methods for screening libraries of complexes for compounds having a desired property, especially, the capacity to agonize, bind to, or antagonize a polypeptide or its cellular receptor. The complexes in such libraries comprise a compound under test, a tag recording at least one step in synthesis of the compound, and a tether susceptible to modification by a reporter molecule. Modification of the tether is used to signify that a complex contains a compound having a desired property. The tag can be decoded to reveal at least one step in the synthesis of such a compound. Other methods for identifying compounds which interact with TGF-R and/or TGF-R_{II} according to the invention or nucleic acid molecules encoding such molecules are, for example, the in vitro screening with the phage display system as well as filter binding assays or "real time" measuring of interaction using, for example, the BIAcore apparatus (Pharmacia). All these methods can be used in accordance with the present invention to identify a compound interfering with the biological activity of TGF-R and/or TGF-R_{II} or the expression of said receptors, or TGF β 1/TGF-R signaling.

It is also well known to the person skilled in the art, that it is possible to design, synthesize and evaluate mimetics of small organic compounds that, for example, can act as a substrate or ligand to a TGF- β receptor. For example, it has been

described that D-glucose mimetics of hapalosin exhibited similar efficiency as hapalosin in antagonizing multidrug resistance assistance-associated protein in cytotoxicity; see Dinh, J. Med. Chem. 41 (1998), 981-987. The gene encoding TGF- β 1 or TGF-R can also serve as a target for screening inhibitors. Inhibitors may

5 comprise, for example, proteins that bind to the mRNA of the gene encoding TGF-R, preferably TGF-R_{II}, thereby destabilizing the native conformation of the mRNA and hampering transcription and/or translation. Furthermore, methods are described in the literature for identifying nucleic acid molecules such as an RNA fragment that

10 mimics the structure of a defined or undefined target RNA molecule to which a compound binds inside of a cell resulting in retardation of cell growth or cell death; see, e.g., WO 98/18947 and references cited therein. These nucleic acid molecules can be used for identifying unknown compounds of pharmaceutical interest and for identifying unknown RNA targets for use in treating a disease. These methods and

15 compositions can be used for identifying compounds useful to reduce expression levels of TGF- β 1 and/or the corresponding receptor(s). The compounds which can be tested and identified according to the method of the invention may be expression libraries, e.g., cDNA expression libraries, peptides, proteins, nucleic acids, antibodies, small organic compounds, hormones, peptidomimetics, PNAs or the like (Milner, Nature Medicine 1 (1995), 879-880; Hupp, Cell 83 (1995), 237-245; Gibbs,

20 Cell 7 (1994), 193-198 and references cited supra). Furthermore, genes encoding a putative regulator of TGF- β 1 and/or which exert their effects up- or downstream of TGF-P1 may be identified using, for example, insertion mutagenesis using, for example, gene targeting vectors known in the art. Said compounds can also be functional derivatives or analogues of known inhibitors. Such useful compounds can

25 be for example transacting factors which bind to TGF-R or TGF-R_{II} or regulatory sequences of the gene encoding it. Identification of transacting factors can be carried out using standard methods in the art. To determine whether a protein binds to the protein itself or regulatory sequences, standard native gelshift analyses can be carried out. In order to identify a transacting factor which binds to the protein or

30 regulatory sequence, the protein or regulatory sequence can be used as an affinity reagent in standard protein purification methods, or as a probe for screening an expression library. The identification of nucleic acid molecules which encode polypeptides which interact with TGF-R or TGF-R_{II} can also be achieved, for example, as described for TGF- β 1 in Scofield (Science 274 (1996), 2063- 2065) by

35 use of the so-called yeast "two-hybrid system". In this system TGF- β 1 is linked to the DNA-binding domain of the GAL4 transcription factor. A yeast strain expressing this fusion polypeptide and comprising a lacZ reporter gene driven by an appropriate promoter, which is recognized by the GAL4 transcription factor, is transformed with a library of cDNAs which will express plant proteins or peptides thereof fused to an

activation domain. Thus, if a peptide encoded by one of the cDNAs is able to interact with the fusion peptide comprising a peptide of, e.g., TGF-R or TGF-R_{II}, the complex is able to direct expression of the reporter gene. In this way, e.g., TGF-R or TGF-R_{II} and the gene encoding each receptor can be used to identify peptides and proteins interacting with TGF-R or TGF-R_{II}. It is apparent to the person skilled in the art that this and similar systems may then further be exploited for the identification of inhibitors. Finally, the present invention relates to the use of a compound identified by the method described above for the preparation of a pharmaceutical composition for the prevention or treatment of a disease, wherein neurogenesis or neuroregeneration has a beneficial effect. The below example explains the invention in more detail.

The present intervention also relates to methods for identifying the effects of treatment or prevention/prophylaxis at the stem cell / precursor cell population, induced by the modulation of the TGF-R- or TGF-R_{II}-System. This may be especially helpful in establishing successful treatment in the individual patient, allowing for example individualized dosing. The diagnostic methods comprise

- (a) systemic application of specific antibodies directed against TGF-R or TGF-R_{II} and labelled with either specific nuclids for nuclear medicine diagnostics (Iodine, Technetium, Fluor 18) or with gadolinium salts, perfluorocarbons or other rare earth products / paramagnetic compounds / iron particles for use in Magnetic Resonance Imaging. In this context it may be necessary to shortly open the blood brain barrier at the subependymal layer, in case there is not enough signal over noise ratio; although this area is highly vascularized, and contrast may be enough for visualisation with a 3 Tesla machine, opening of the BBB may be of additional help. This may be either done with i.v. hyperosmolar solutions (e.g. glycerol) or with VEGF (Vascular Endothelial Growth Factor).
- (b) systemic application of oligonucleotides (same molecules as mentioned above) specific for TGF-R or TGF-R_{II}: They would be labelled as follows:
Gd or ¹¹¹In - DTPH (5'XXXXXXXXXXXXXXXXXXXX3'-Biotin) - (SA- either OX 26, 8D3 or Ak-HIR) (whereby Gd is used for MRI, ¹¹¹In is used for radiodiagnostics; OX 26 is used for mouse experiments and targets the mouse transferrin receptors, 8D3 is a mouse anti rat transferrin receptor antibody, AK-HIR is an antibody directed at the human Insulin receptor). These compounds would only hybridize and signal in those cells that have the active mRNA for TGF-R or TGF-R_{II}. DTPH is used as a chelate-building agent, the Ak-HIR uses the Insulin receptor to shuttle the oligonucleotide through the different barriers,

in case of the transferrin receptor antibodies the latter is used for the transmembrane shuttle. There is a differential hybridization stability in those cells where a large number of mRNA is available and therefore a much stronger signal may be detected (Susuki T, Schlachetzki F, et al. J. Nucl. Med. 45: 1766-1775, 2004, Susuki T, Zhang Y, Zhang Y-f, Schlachetzki F, Pardridge et al., Mol. Imaging 2005, 3, 356-363).

- (c) systemic application of oligonucleotides (same molecules as mentioned above) specific for Doublecortin (DCX) with identical labelling as in (b) (cf. WO 2004067751)

Preferably, in a pharmaceutical composition, such compound as described above is combined with a pharmaceutically acceptable carrier. "Pharmaceutically acceptable" is meant to encompass any carrier, which does not interfere with the effectiveness of the biological activity of the active ingredient and that is not toxic to the host to which it is administered. Examples of suitable pharmaceutical carriers are well known in the art and include phosphate buffered saline solutions, water, emulsions, such as oil/water emulsions, various types of wetting agents, sterile solutions etc.. Such carriers can be formulated by conventional methods and the active compound can be administered to the subject at an effective dose. An "effective dose" refers to an amount of the active ingredient that is sufficient to affect the course and the severity of the disease, leading to the reduction or remission of such pathology. An "effective dose" useful for treating and/or preventing these diseases or disorders may be determined using methods known to one skilled in the art. Administration of the suitable compositions may be effected by different ways, e.g. by intravenous, intraperitoneal, subcutaneous, intramuscular, topical or intradermal administration. The route of administration, of course, depends on the kind of therapy and the kind of compound contained in the pharmaceutical composition. Furthermore, the compounds of the present invention may be mixed and administered together with liposomes, complex forming agents, receptor targeted molecules, solvents, preservatives and/or diluents.

Preferred are pharmaceutical preparations in form of infusion solutions or solid matrices for continuous release of the active ingredient, especially for continuous release of at least one antisense oligonucleotide or variants or mimetics thereof. More preferred are pharmaceutical preparations in form of solutions or solid matrices suitable for local administration into the brain.

The dosage regimen will be determined by the attending physician and other clinical factors. As is well known in the medical arts, dosages for any one patient depends on many factors, including the patient's size, body surface area, age, sex, the particular compound to be administered, time and route of administration, the kind of therapy, general health and other drugs being administered concurrently.

The present invention relates to pharmaceutical preparations comprising at least one oligonucleotide, variants or mimetics thereof, as disclosed above. Instead of or in addition to the at least one antisense oligonucleotide at least one antisense compound could be present. Antisense compounds refer to vectors allowing to transcribe an antisense oligonucleotide, especially one of the antisense oligonucleotides as disclosed herein or to ribozymes, external guide sequences (EGS), oligozymes, and short catalytic RNAs or catalytic oligonucleotides which hybridize to the target nucleic acid encoding TGF-R or TGF-R_{II}. Said antisense compound inhibits the expression of TGF-R or TGF-R_{II} and preferably of is capable of decreasing the amount of TGF-R or TGF-R_{II} formed, respectively.

In a preferred embodiment of the present invention, the disease that can be prevented and/or treated is a neurodegenerative disorder, a neuroinflammatory disorder of the CNS, an acute ischemic or traumatic brain hypoxic brain lesion. Preferred examples of neurodegenerative or neuroinflammatory disorders are Alzheimer's diseases, Parkinson's disease, Creutzfeldt Jakob disease (CJD), new variant of Creutzfeldt Jakobs disease (nvCJD), Hallervorden Spatz disease, Huntington's disease, multisystem atrophy, dementia, frontotemporal dementia, motor neuron disorders, amyotrophic lateral sclerosis, spinal muscular atrophy, spinocerebellar atrophies (SCAs), schizophrenia, affective disorders, major depression, meningoencephalitis, bacterial meningoencephalitis and viral meningoencephalitis (prevention of postinflammatory depression of stem cell proliferation), CNS autoimmune disorders, like Multiple Sclerosis (MS), acute ischemic / hypoxic lesions, CNS trauma, head trauma, arteriosclerosis, atherosclerosis, microangiopathic dementia, Binswanger' disease, leukoaraiosis, AIDS-related dementia, , fragile X-associated tremor/ataxia syndrome (FXTAS), progressive supranuclear palsy (PSP), striatonigral degeneration (SND), olivopontocerebellar degeneration (OPCD), Shy Drager syndrome (SDS); retinal degeneration, macular degeneration, retinitis pigmentosa, cochlear degeneration, cochlear deafness. Also age dependant decrease of stem cell renewal may be addressed.

Examples

Example 1

5 TGF- β 1 inhibits proliferation of adult rodent neural stem and precursor cells.

Adult female mice (various strains) or Fischer-344 rats (3–4 months; Charles River, Germany) are killed, and brains and spinal cords are removed and put in 4°C DPBS (PAN, Germany) with 4.5 gm/l glucose (Merck, Germany) (DPBS/glu). Overlying meninges and blood vessels are removed. Hippocampus and ependymal zones, including subependymal and subventricular zones from the lateral wall of the lateral ventricle (SVZ), are aseptically removed. The dissected tissue is transferred to fresh DPBS/glu, washed once, transferred to Petri dishes, and dissociated mechanically. The cell suspension is washed in DPBS/glu to rinse off excess blood and resuspended in PPD solution containing 0.01% papain (Worthington Biochemicals, England), 0.1% dispase II (Boehringer Mannheim, Mannheim, Germany), 0.01% DNase I (Worthington Biochemicals), and 12.4 mM MgSO₄ in HBSS (PAN) without Mg₂/Ca₂ (PAA, Germany) and digested for 30 to 40 minutes at room temperature. The cell suspension is triturated every 10 minutes. Dissociated cells are collected and resuspended in serum-free DMEM/F12 medium containing 2 mM L-glutamine and 0.1 gm/l penicillin/streptomycin and washed three times with accurate trituration. Finally the single-cell suspension is resuspended in NB medium (Gibco BRL, Germany) supplemented with B27 (Gibco BRL) (NB/B27), 2 mM L-glutamine (PAN), 0.1 gm/l penicillin/streptomycin (PAN), 2 g/ml heparin (Sigma, Taufkirchen, Germany), 20 ng/ml bFGF-2 (R&D Systems, Germany), and 20 ng/ml EGF (R&D Systems, Germany). Viable cells are counted by trypan blue exclusion assay in a hemocytometer. Cells are seeded in T-25 culture flasks and cultures are maintained at 37°C in an incubator with 5% CO₂. Single cells begin to form spheres within 5 to 7 days of suspension culture and continue to grow in mass and number during the next weeks. Half of the medium is changed every 7 days. Cells from passage numbers 3 to 20 are used for the experiments (Wachs, F. P., S. Couillard-Despres, et al., Lab Invest 2003, 83(7), 949-962). The cultures of neural stem and precursor cells are further referred to as NSC's. For the dissociation process, the culture medium containing floating neurospheres is collected in a 15-ml centrifuge tube and centrifuged at 120 rcf for 5 minutes. The pellet is resuspended in 200 μ l of Accutase (Innovative Cell Technologies Inc., distributed by PAA) and triturated approximately 10 times using a pipette. Then, the cell suspension is incubated at 37°C for 10 minutes. Dissociated spheres are again triturated and resuspended in 800 μ l of NB/B27 medium. Dissociated cells are centrifuged at 120 rcf for 5 minutes and resuspended in NB/B27 medium. An aliquot is counted by trypan blue exclusion

assay in a hemocytometer to determine the amount of viable cells. Cells (10^5) are plated in T75 culture flasks for long-term passaging (10 ml of culture medium per flask) in NB/B27 medium. The cells obtained after Accutase treatment of primary neurospheres proliferate and yield secondary neurospheres. Secondary neurospheres are passaged 7 to 9 days after plating primary neurosphere cells. Similar to primary cultures and primary neurospheres, single cells obtained after dissociation of secondary neurospheres proliferate and yield tertiary neurospheres (Wachs, F. P., S. Couillard-Despres, et al., Lab Invest 2003, 83(7), 949-962).

10^4 NSC's are seeded in 12-well plates in NB/B27 medium in a volume of 1 ml and grow for 7 days. 2 hours, 3 days and 6 days after seeding the cells are stimulated by addition of various concentrations (0, 2.5, 5, 10, 50 and 100 ng/ml) of recombinant human Transforming Growth Factor $\beta 1$ (TGF- $\beta 1$) (R&D Systems, Germany). On day 7 the cultures are dissociated by the use of Accutase™ and viable cells are counted by trypan blue exclusion assay in a hemocytometer. *In vitro* TGF- $\beta 1$ inhibits the proliferation of adult neural stem and precursor cells in a dose dependant manner (figure 1A).

A similar effect was observed on human fetal neural precursors cells. Treatment with 50 ng/ml of TGF- $\beta 1$ reduced cell proliferation to about 50% of controls within 7 days (figure 1B).

Example 2

The effect of TGF- $\beta 1$ on neural stem and precursor cells is reversible

To determine, whether the TGF- $\beta 1$ induced growth-inhibition is a reversible effect, NSC's are stimulated with 10 ng/ml TGF- $\beta 1$ for 7 days according to the protocol described in example 1. After dissociation, viable cells are counted by Trypan Blue exclusion assay in a hemocytometer and 10^4 growth factor-stimulated NSC's are reseeded and cultured with or without 10 ng/ml TGF- $\beta 1$ according to the protocol described in example 1. This dissociation/counting/reseeding procedure is performed every 7 days. As shown in figure 2, after 3 weeks of culture the proliferation rate of initially TGF- $\beta 1$ -treated cells now grown without TGF- $\beta 1$ returns to normal when compared to formerly untreated cells. This indicates that the effect of TGF- $\beta 1$ on adult neural stem and precursor cells is reversible. Long term incubation with TGF- $\beta 1$ does not further decrease cell proliferation.

Example 3

Antibodies against TGF- βR_{II} can reduce TGF- $\beta 1$ effects on adult rodent NSC's

Unstimulated seven-day-old neurospheres of low passage number are dissociated by the use of Accutase™ as described in example 1. The resulting single-cell

suspension was used for blocking analysis. Adult rodent NSC's were seeded at a density of 10^4 cells in 12-well plates in NB/B27 medium in a volume of 1 ml. 2 hours after seeding and 1 hour prior to stimulation with 10 ng/ml TGF- β 1, various concentrations of neutralizing anti-TGF- β R_{II} antibodies (R&D Systems, Germany) were added to the culture medium. 3 days and 6 days after seeding the cells are re-stimulated by addition of anti-TGF- β R_{II} antibodies and TGF- β 1 identical to the procedure performed on day 1. On day 7 the cultures are dissociated by the use of Accutase™ and viable cells are counted by trypan blue exclusion assay in a hemocytometer. Interestingly, addition of the anti-TGF- β R_{II} antibodies itself reduces proliferation of NSC's. Antibodies against TGF- β R_{II} are only able to partially inhibit TGF- β 1-induced effects even in the highest concentrations used (10 μ g/ml) (figure 3).

Example 4

Soluble TGF-R_{II} completely inhibits TGF- β 1 induced suppression of NSC proliferation

According to the manufacturers protocol (R&D Systems, Germany), a DNA sequence encoding the 159 amino acid residue extracellular domain of human TGF- β R_{II} (Lin et al., Cell 1992, 68(4), 775-785) was fused to the Fc region of human IgG1 and the chimeric protein was expressed in a mouse myeloma cell line NSO. Unstimulated seven-day-old neurospheres of low passage number are dissociated by the use of Accutase™ as described in example 1. The resulting single-cell suspension was used for blocking analysis. Adult rodent NSC's were seeded at a density of 10^4 cells in 12-well plates in NB/B27 medium in a volume of 1 ml. 2 hours after seeding and 1 hour prior to stimulation with 10 ng/ml TGF- β 1, various concentrations of bioactive soluble recombinant human TGF- β sR_{II}/Fc Chimera (R&D Systems, Germany) were added to the culture medium. 3 days and 6 days after seeding the cells are re-stimulated by addition of TGF- β sR_{II}/Fc Chimera and TGF- β 1 identical to the procedure performed on day 1. On day 7 the cultures are dissociated by the use of Accutase™ and viable cells are counted by trypan blue exclusion assay in a hemocytometer. Interestingly, addition of the TGF- β sR_{II}/Fc Chimera are able to completely block TGF- β 1-induced effects in a dose dependant manner (data not shown). Clearly, abrogation of active TGF- β 1 in the cell culture supernatant by pre-administration of a soluble recombinant human TGF- β sR_{II}/Fc Chimera (soluble TGF- β R_{II}) completely blocks TGF- β 1-induced growth-suppression of adult neural stem and precursor cells (Figure 4).

Example 5

TGF- β R_{II}-expressing cells can be isolated using Cell sorting techniques.

Current methods do not allow fast and reliable isolation and purification of neural stem and precursor cells. To investigate the possibility of isolating pure neural stem and precursor cell populations based on the expression of defined surface markers, we isolate neural stem and precursor cells due to the expression of the TGF- β R_{II} by different techniques. It is possible to isolate TGF- β R_{II}-expressing neural stem and precursor cells with two techniques: i) FACS-sorting (data not shown), and ii) MACS-sorting. Dissociated adult neural stem and precursor cells are incubated with 10 μ g/ml of primary antibodies against TGF-R_{II} (R&D Systems, Germany) for 20 min at room temperature. After 1 washing step with PBS the cells are incubated with the secondary antibody rabbit-anti-goat-PE (1:500) (Dianova). After 1 washing step with PBS the cells are stained with tertiary antibodies against PE coupled to paramagnetic beads according to the manufacturers protocol (Miltenyi Biotech, Germany). The cell suspension is magnetically sorted using the MACS-system according to the manufacturers protocol (Miltenyi Biotech, Germany) and negative and positive cells after sorting are counted and taken in culture (figure 5). Approximately 20% of all sorted cells stained positive for TGF- β R_{II}.

Example 6

Antisense oligonucleotides against TGF- β R_{II} inhibit the TGF- β 1 induced down-regulation of adult neural stem and precursor cell proliferation in vitro.

Cells were prepared, dissociated and plated as described in example 1. Cells were then incubated for 1 week with or without 10ng/ml TGF- β 1, 10 μ M TGF- β R_{II} antisense oligonucleotide 5' – cagcccccgacccatg – 3' (SEQ ID NO: 3), sense oligonucleotide 5' – catgggtcgggggctg – 3', or missense 5' – catccccggaccgctg – 3'. Oligonucleotides were phosphothioate-modified and medium with oligonucleotides was changed daily. Note that the TGF- β 1 induced inhibition of neural stem and precursor proliferation was completely and specifically blocked by the antisense (SEQ ID NO: 3) treatment (figure 6).

Example 7

In vivo treatment with TGF β R_{II} specific antisense oligonucleotides rescues the TGF- β 1 induced blockade of cell proliferation in the adult brain.

This example demonstrates i) the effect of TGF- β 1 infusion on neural stem and progenitor cell proliferation in vivo and ii) the rescue of this effect by TGF β R_{II} antisense oligonucleotide treatment. Therefore, the following experiment was designed:

TGF- β 1 was infused intraventricularly for two weeks followed by a co-infusion of TGF- β 1 with oligonucleotides. Animal experiments were carried out in accordance

with the European Communities Council Directive of 24 November 1986 (86/609/EEC). Stainless steel canules connected to osmotic minipumps (Model 2001, Alza, Stadt, Land) were implanted into two months-old male Fischer-344 rats (n=24) for intracerebroventricular infusion as described. The animals received either

5 recombinant TGF- β 1 (500 ng/ml present in the pump) or artificial cerebrospinal fluid (aCSF) as control (n=8 each) at a flow rate of 0.5 μ l/hr for two weeks. After the second week, the pumps were changed and aCSF, TGF- β 1 (500 ng/ml present in the pump), or TGF- β 1 (500 ng/ml present in the pump) in combination with phosphothioate oligonucleotides (1,64 mM concentration present in the pump) was

10 infused into the ventricles for the following two weeks. Oligonucleotides were as described in example 6. On day 27, animals received a single intraperitoneal injection of 200 mg/kg bromo-deoxyuridine (BrdU). One day later, animals were intracardially perfused with 4% paraformaldehyde. Tissue was processed for chromogenic or epifluorescence immunodetection in 40 μ m sagittal sections as

15 described. Epifluorescence analysis was done using a Leica microscope (Leica Mikroskopie und Systeme GmbH, Wetzlar, Germany) equipped with a SpotTM digital camera (Diagnostic Instrument Inc, Sterling Heights, USA) or a confocal scanning laser microscope (Leica TCS-NT, Bensheim, Germany). Primary antibodies were: rat α -BrdU 1:250 (Oxford Biotechnology, Oxford, UK). Secondary antibodies were:

20 donkey α -goat, mouse, rabbit or rat conjugated with fluorescein (FITC), rhodamine X (RHOX), CY5 or biotin 1:500 (Jackson Immuno Research, West Grove, PA, USA). For counting, a systematic and random procedure was used. BrdU positive cells were counted within three 50 μ m x 50 μ m counting frames per section located at the lowest, middle and upper part of the SVZ. Positive profiles that intersected the

25 uppermost focal plane (exclusion plane) or the lateral exclusion boundaries of the counting frame were not counted. The total counts of positive profiles were multiplied by the ratio of reference volume to sampling volume in order to obtain the estimated number of BrdU-positive cells for each structure. All extrapolations were calculated for one cerebral hemisphere and should be doubled to represent the total

30 brain values. Data are presented as mean values \pm standard deviations (SD). Statistical analysis was performed using the unpaired, two-sided t-test comparison – Student's t-test between the TGF- β 1 treated and control groups (StatView Software, Cary, NC, USA). The significance level was assumed at $p < 0.05$.

Figure 7 demonstrates the TGF- β 1 induced down-regulation of cell proliferation in the

35 hippocampal dentate gyrus (figure 7A) and in the subventricular zone (figure 7B). Treatment with missense oligonucleotide did not block this effect. In contrast, antisense oligonucleotide treatment (SEQ ID NO: 3) blocked the TGF- β 1 effect (figure 7 A and B).

Example 8

In vivo treatment with TGF- β RII specific antisense oligonucleotides prevents from TGF- β 1 induced blockade of cell proliferation in the adult brain.

- 5 This example demonstrates that antisense oligonucleotide treatment against TGF- β RII can prevent from TGF- β 1 induced down-regulation of cell proliferation in the adult brain.
- Oligonucleotides were infused intraventricularly for one week followed by a co-infusion of TGF- β 1 with oligonucleotides. Animal experiments were carried out in accordance with the European Communities Council Directive of 24 November 1986 (86/609/EEC). Stainless steel canules connected to osmotic minipumps (Model 2001, Alza, Stadt, Land) were implanted into two months-old male Fischer-344 rats (n=24) for intracerebroventricular infusion as described. The animals received either phosphothioate oligonucleotides (1,64 mM concentration present in the pump) or aCSF during the first week, and aCSF, TGF- β 1 (500 ng/ml present in the pump), or a co-infusion of TGF- β 1 (500 ng/ml present in the pump) and phosphothioate oligonucleotides (1,64 mM concentration present in the pump) during the second and third week. Oligonucleotides were described in example 6. On day 20, animals received a single intraperitoneal injection of 200 mg/kg bromo-deoxyuridine (BrdU). One day later, animals were intracardially perfused with 4% paraformaldehyde. Tissue was processed and analyzed as described in example 7. Figure 8 demonstrates that the TGF- β 1 induced down-regulation of cell proliferation in the hippocampal dentate gyrus (figure 8A) and in the subventricular zone (figure 8B) can be prevented by pre-treatment with TGF- β RII antisense oligonucleotide (SEQ ID NO: 3) treatment.

Example 9

Pharmaceutical formulation comprising at least one antisense oligonucleotide

- 30 Three representative aqueous formulations for the antisense oligonucleotides:
1. in aCSF: 148,0 mM NaCl, 3,0 mM KCl, 1,4 mM CaCl₂, 0,8 mM MgCl₂, 1,5 mM Na₂HPO₄, 0,2 mM NaH₂PO₄, pH 7.4, 100 μ g/ml rat serum albumin, 50 μ g/ml Gentamycin
 - 35 2. in 0,9% NaCl
 3. in H₂O